

JAMIE A. DAVIES



# life unfolding

how the human body creates itself

**'A demanding but wonder-filled  
account of the simple interactions  
that create complex structures.'**

*New Scientist*

How is it possible that all the complexity of a living human being — a brain of billions of neurons, the filigree-work of blood capillaries, the solidity of bones, the fully functioning system of energy acquisition, self-maintenance, and repair — can arise from a single fertilized egg?

This book presents the emerging picture of how the human body makes itself, for self-organization is the key. Drawing on cutting edge science, Jamie A. Davies takes us step by step through the processes that together build a human body. The resulting story, of simple rules building exquisite complexity, is proving to be more extraordinary than we could ever have imagined.

Cover photograph: Hybrid Medical Animation/Science Photo Library.

popular science

**OXFORD**  
UNIVERSITY PRESS

[www.oup.com](http://www.oup.com)

ISBN 978-0-19-967354-4



£10.99 RRP

\$19.95 USA



# Life Food Gardens

Draves

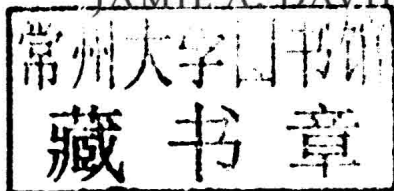
Oxford

# Life Unfolding

How the human body creates itself



JAMIE A. DAVIES



OXFORD  
UNIVERSITY PRESS

OXFORD

UNIVERSITY PRESS

Great Clarendon Street, Oxford, OX2 6DP,  
United Kingdom

Oxford University Press is a department of the University of Oxford.  
It furthers the University's objective of excellence in research, scholarship,  
and education by publishing worldwide. Oxford is a registered trade mark of  
Oxford University Press in the UK and in certain other countries

© Jamie A. Davies 2014

The moral rights of the author have been asserted

First published 2014

First published in paperback 2015

Impression: 1

All rights reserved. No part of this publication may be reproduced, stored in  
a retrieval system, or transmitted, in any form or by any means, without the  
prior permission in writing of Oxford University Press, or as expressly permitted  
by law, by licence or under terms agreed with the appropriate reprographics  
rights organization. Enquiries concerning reproduction outside the scope of the  
above should be sent to the Rights Department, Oxford University Press, at the  
address above

You must not circulate this work in any other form  
and you must impose this same condition on any acquirer

Published in the United States of America by Oxford University Press  
198 Madison Avenue, New York, NY 10016, United States of America

British Library Cataloguing in Publication Data  
Data available

Library of Congress Cataloguing in Publication Data  
Data available

ISBN 978-0-19-967353-7 (Hbk.)

ISBN 978-0-19-967354-4 (Pbk.)

Printed and bound in Great Britain by  
Clays Ltd, St Ives plc

Links to third party websites are provided by Oxford in good faith and  
for information only. Oxford disclaims any responsibility for the materials  
contained in any third party website referenced in this work.

## LIFE UNFOLDING

Jamie A. Davies is Professor of Experimental Anatomy at the University of Edinburgh. He has published over 100 research papers in the field of mammalian development, authored *Mechanisms of Morphogenesis* (Academic Press, 2<sup>nd</sup> edition 2013), and edited three multi-author books in the fields of development, stem cells and tissue engineering. He is a Fellow of the Society of Biology, a Fellow of the Royal Society of Medicine, and the Royal Society of Arts.



*To Katie*





## ACKNOWLEDGEMENTS

I would like to thank Dr Katie Brooks for her encouragement, for her patience when writing this book had made me lose track of the time *yet again*, and for her very helpful comments on the first draft.

I would also like to thank the following colleagues in the field of developmental biology and related disciplines, who did me the enormous service of checking sections of this book in which they have world-leading expertise. They are James Briscoe, Mike Clinton, Kim Dale, Megan Davey, Peter Kind, Val Wilson, Georgia Perona-Wright, Thomas Theil, and Cheryl Tickle. For any errors that remain, the blame is entirely mine. Finally, I would like to thank Latha Menon and her colleagues at Oxford University Press for their immensely helpful editorial advice.

The title *Life Unfolding* is inspired by a phrase from Gillian K. Ferguson's biological poem, *Not in charge*.

## ETHICAL STATEMENT

This book, which describes the mechanisms of human development, includes published knowledge that has been obtained by study of human embryonic and foetal material and by experimentation on living animals. Because academic publishers and funders of research require that all work be ethically approved by the relevant independent ethics committees, I have assumed that these experiments were conducted according to the standards of the day. Ethical standards do change with time, and some work done long ago would not be permitted now. Mention of experimental results in this book does not imply personal ethical endorsement of the experimental method, by either the author or publisher.

## A NOTE ON REFERENCES AND FOOTNOTES

This book is aimed at a general readership and, for this reason, the mechanisms of human development have been described with as little molecular detail as is possible. Long lists of unpronounceable protein names are tedious even to professional biologists and would be out of place in a book that is meant to present deep principles. Nevertheless, to help committed students of biology and medicine to connect the events in this book with papers on molecular embryology, occasional technical footnotes indicate which details the main text is avoiding. Understanding these technical notes is not necessary for understanding the book—they are present only for a small subset of the readership with particular needs.

For similar reasons, the main text uses superscript numbers to cite technical research references, especially in support of statements that are at variance with a traditional view. In the interests of conciseness, these citations have been kept to a minimum and, instead of following the normal academic convention of citing original experimental reports, they instead often point to review articles that provide a convenient gateway to experimental literature. No explicit citations are given for material that is well covered in standard textbooks. The alternative, of having the text interrupted by thousands of citation numbers, as would happen in a research monograph, would not be appropriate here.

A list of accessible books for further reading on particular topics is given at the end of the book.



# CONTENTS

<i>Acknowledgements</i>	ix
<i>Ethical Statement</i>	x
<i>A Note on References and Footnotes</i>	xi
<b>Introduction</b>	<b>1</b>
1 Confronting an Alien Technology	3
<b>Part I First Sketch</b>	<b>15</b>
2 From One Cell to Many	17
3 Making a Difference	28
4 Laying Down a Body Plan	37
5 Beginning a Brain	53
6 Long Division	65
<b>Part II Adding Details</b>	<b>81</b>
7 Fateful Conversations	83
8 Inner Journeys	92
9 Plumbing	106
10 Organizing Organs	123
11 Taking Up Arms (and Legs)	135
12 The Y and How	145
13 Wired	161
<b>Part III Refinement</b>	<b>175</b>
14 Dying to be Human	177
15 Making your Mind Up	183
16 A Sense of Proportion	194
17 Making Friends and Facing Enemies	208
18 Maintenance Mode	224

## CONTENTS

<b>Part IV Perspectives</b>	<b>245</b>
19 Perspectives	247
Glossary	260
Technical References	270
Further Reading	289
Sources of Quotations at Heads of Chapters	292
Index	295

# INTRODUCTION

*The possession of knowledge does not kill  
the sense of wonder and mystery.  
There is always more mystery.*

Anaïs Nin



